UNIVERSITY OF CALIFORNIA

The Dynamics of Behavior Change: Evidence from Energy Conservation

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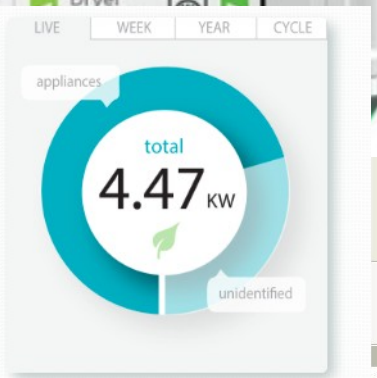

Research Question

How can we use information to motivate people to conserve energy at home?

- How do consumers stay engaged?
- What framing is most effective to keep them engaged?
  - health/cost framing
- How long does behavior change last?

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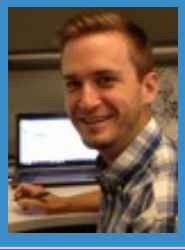

Victor Chen
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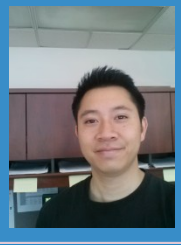
Electrical Engineering



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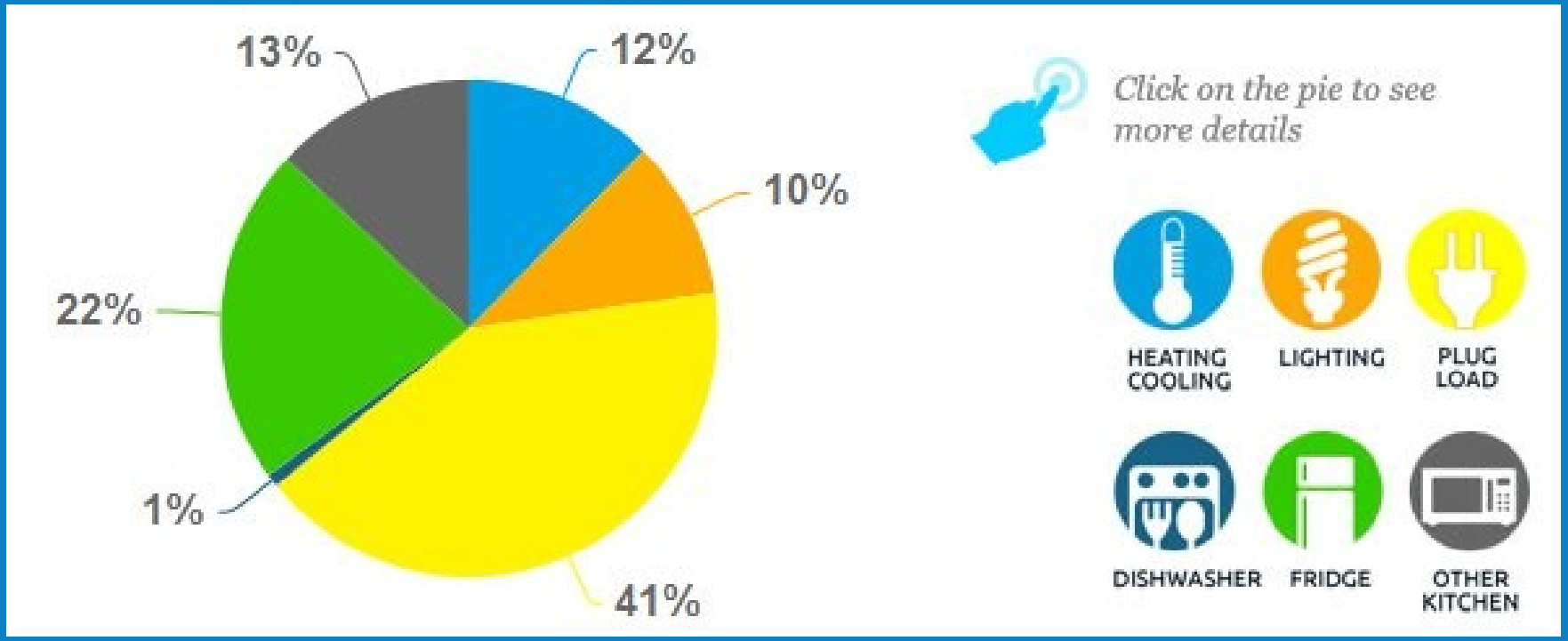
Real time appliance energy use



The Challenges of Behavior Change

- US electricity generation > 40% of CO_2 emissions.
- Household electricity is “invisible” to the consumer
- Inattentive, present-biased consumers
- Electricity is cheap (Residential electricity bills are small compared to total household budget)

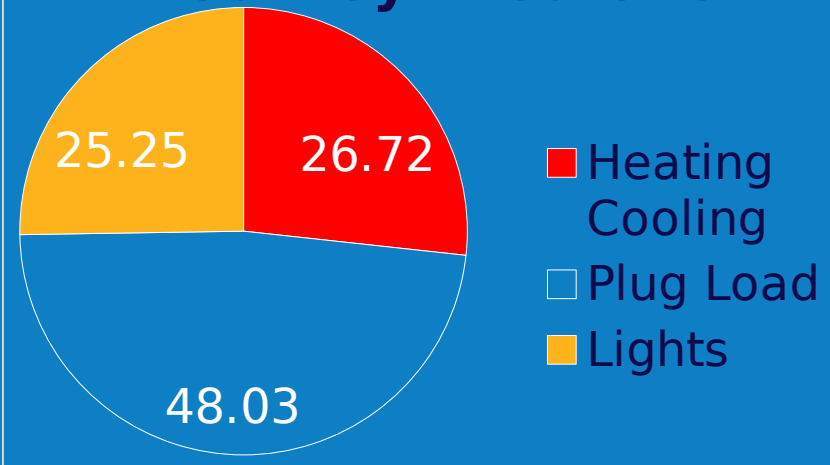
Avg. Monthly Electric Bill: $65-135 (50 largest utilities); Price per kWh: ~11-13 cents/kWh

- Pollution and social costs of energy production are outside of any market transaction
- Behavior change is hard and it is reversible

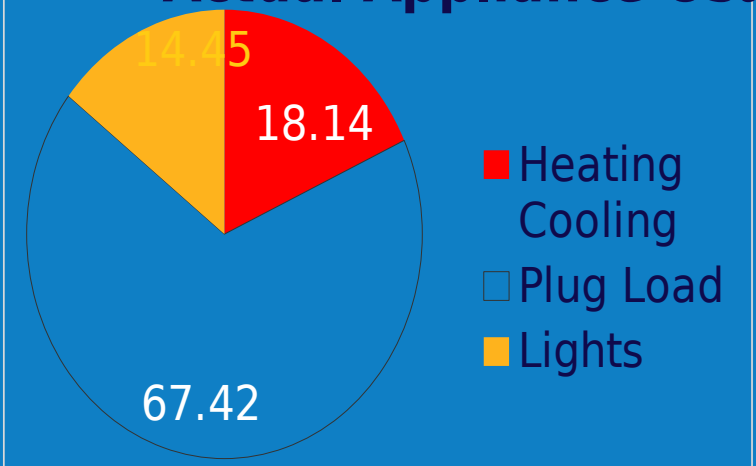
Consumer Misperception of Appliance Usage

Households overestimate lighting and HVAC use by 75% and underestimate plug load usage by 29%

Survey Prediction



Actual Appliance Usage



Correct Guesses = 0 out of 137 households !

6 out of 132 correctly guessed Heating and Cooling share

2 out of 132 correctly guessed Plug Load

6 out of 132 correctly guessed Lighting

N= 132 households out of 137 households

Is Information Effective at reducing electricity usage?

Realize that there is a problem

Identifies cost of behavior of deviation from peers

Realize possibilities to influence the problem

Identifies the impact of specific behavior change

Weigh motives vs cost of action
- Personal values
- Social norms
- Pecuniary incentives

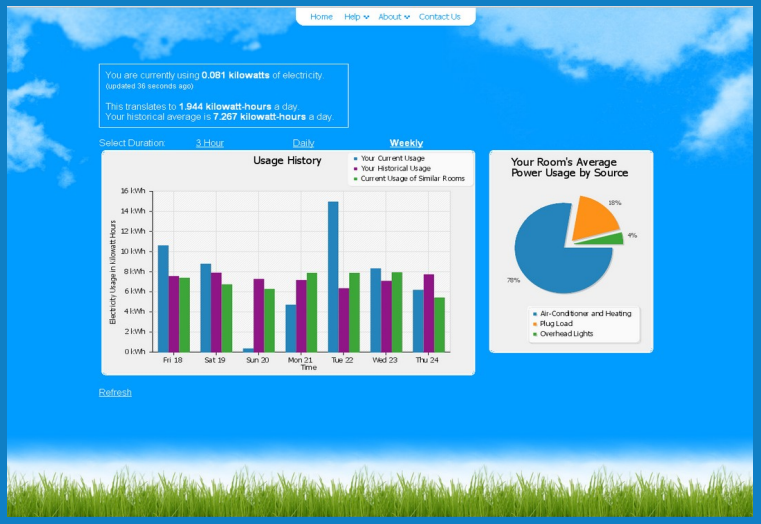
Frame message to motivate behavior

Take action
- Turn on/off lights
- Use of appliances
- Setting the thermostat

Repeated prompts to form new persistent habit

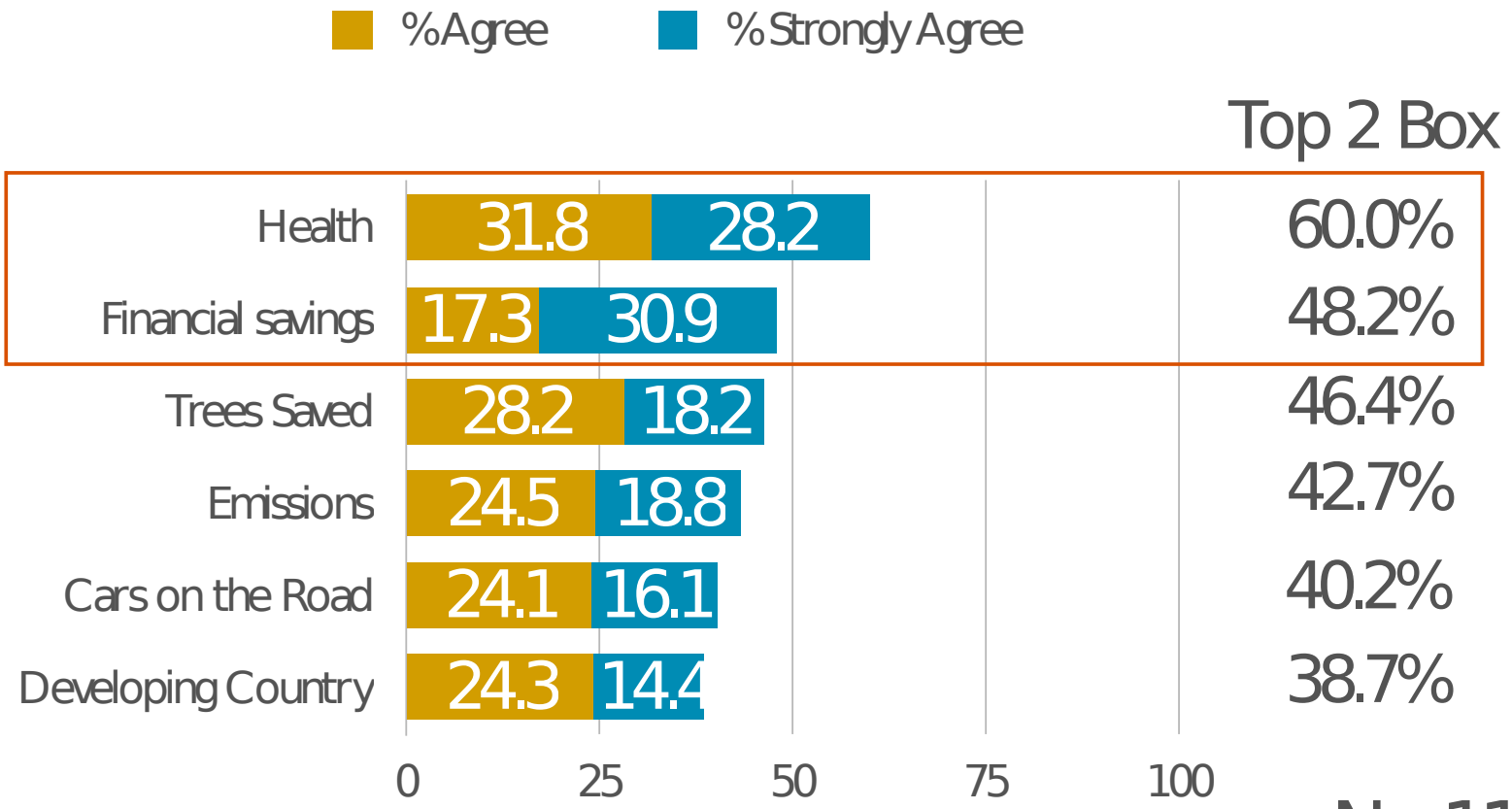
Messages

UCLA Residence Hall: 66 rooms



20% reduction in energy consumption

Selecting Powerful Messages: Pre-Survey



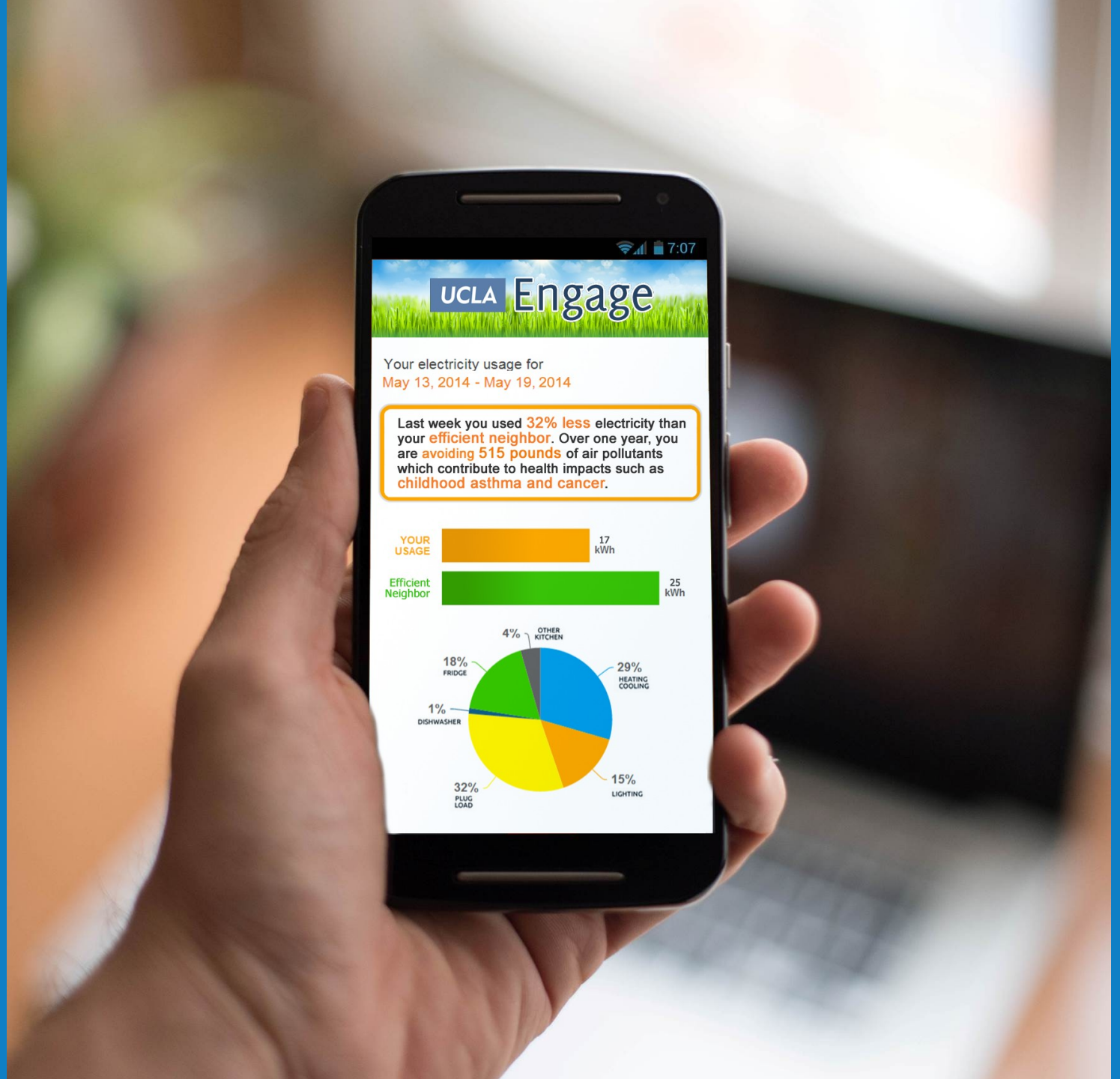
N=110

Health and Financial are the top ranking messages.

Price vs Non-Price messages

Information about cost of energy use

Information about impact of energy use on pollution and health


7:07
UCLA Engage
Your electricity usage for
May 13, 2014 - May 19, 2014
Last week you used 32% less electricity than your efficient neighbor. Over one year, you are avoiding 515 pounds of air pollutants which contribute to health impacts such as childhood asthma and cancer.
YOUR USAGE
17 kWh
Efficient Neighbor
25 kWh
4% OTHER KITCHEN
18% FRIDGE
29% HEATING COOLING
1% DISHWASHER
32% PLUG LOAD
15% LIGHTING

Framing Conservation

Your Impact

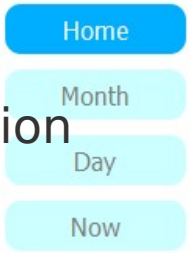
Last week you used **29** **more** electricity than your efficient neighbors.
You spend **$2** **mor%** r one year.
6

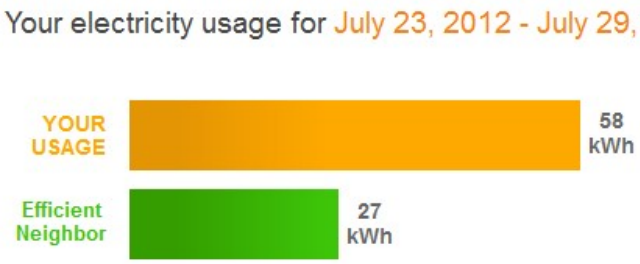
Your Impact

Last week you used **29% more** electricity than your efficient neighbors.
Over one year, you are **adding 456** pounds of air pollutants which contribute to health impacts such as **childhood asthma and cancer**.

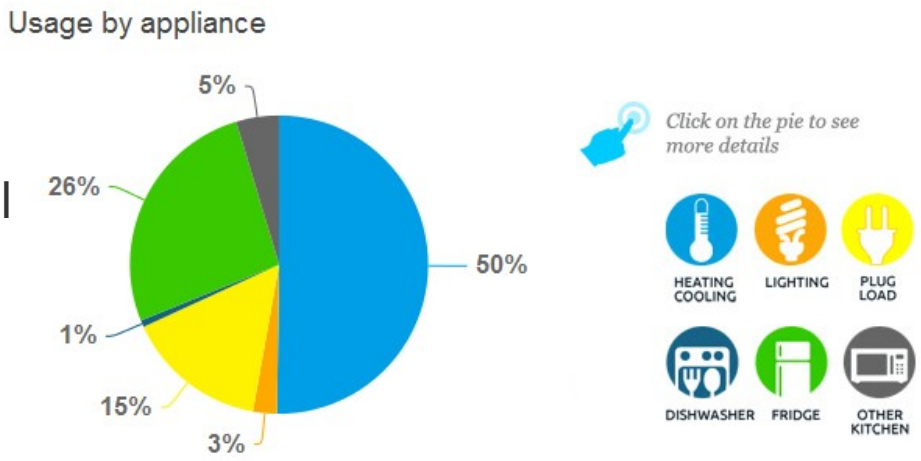
<< Treatment Message

Historical Consumption Tabs >>





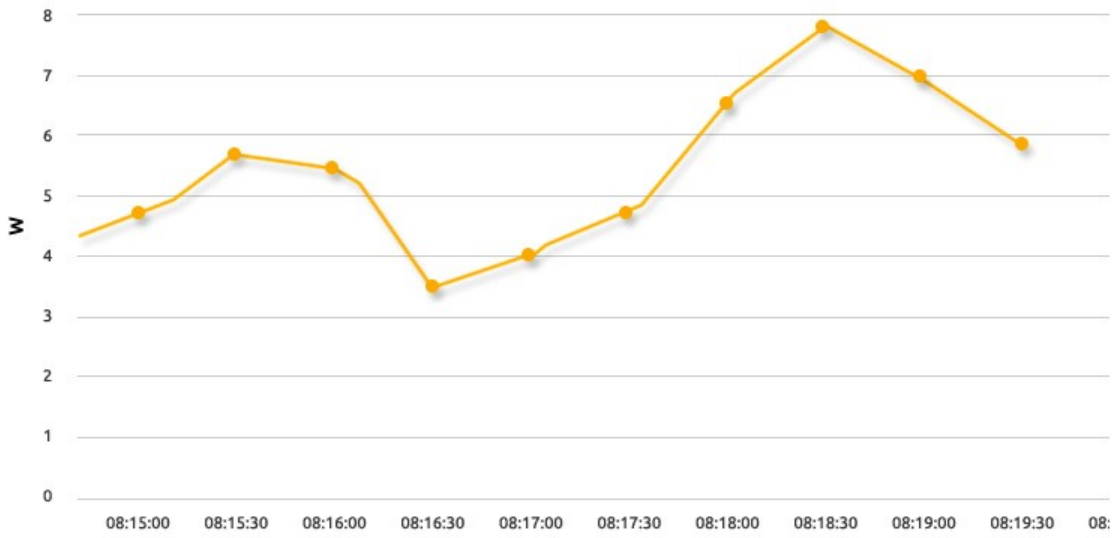
Appliance Level Summary* >>




HOME
ENERGY REPORT
ENERGY SAVING TIPS
ABOUT
CONTACT US
UCLA Engage
Month
Week
Day
Real Time
Month: March 2012
SLIDE
SLIDE
100 kWh
01/02
01/03
01/04
01/05
01/06
01/07
01/08
01/09
01/10
01/11
YOUR USAGE
EFFICIENT NEIGHBOR

Month
Week
Day
Real Time

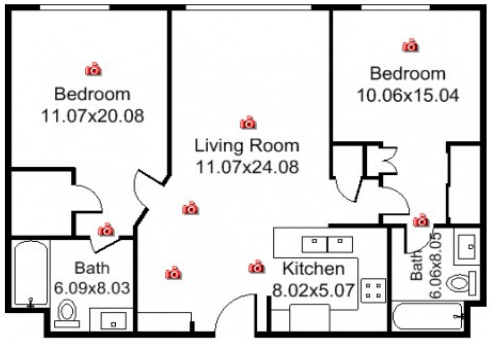
Real Time



This graph shows the current rate at wchich you use electricity, measured in Watt (W).

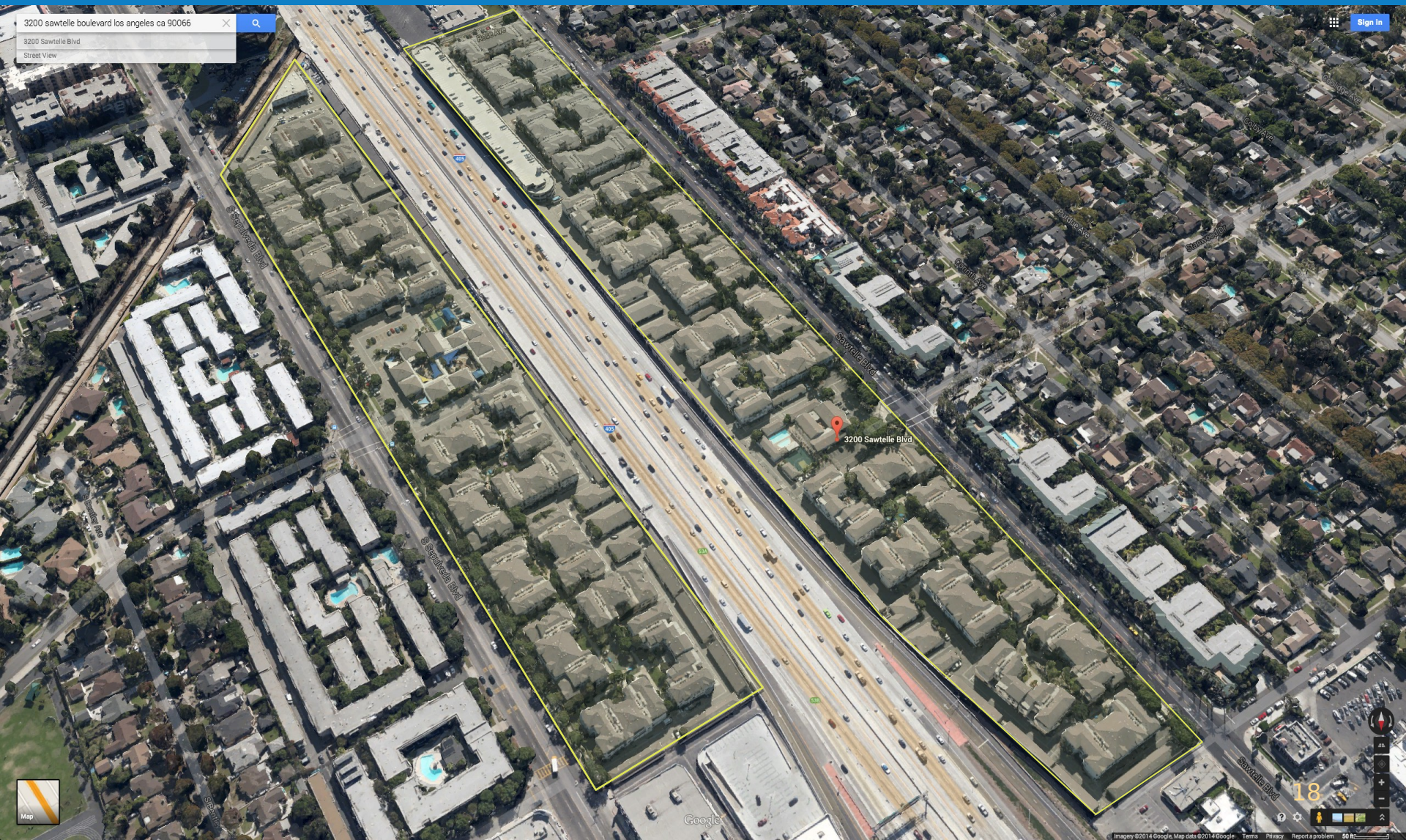
Experimental site: University Village

- 120 apartments equipped with monitoring technology
- Married/partnered graduate students
- With or without children
- Identical appliances:
  - refrigerator,
  - microwave,
  - stove,
  - dishwasher.

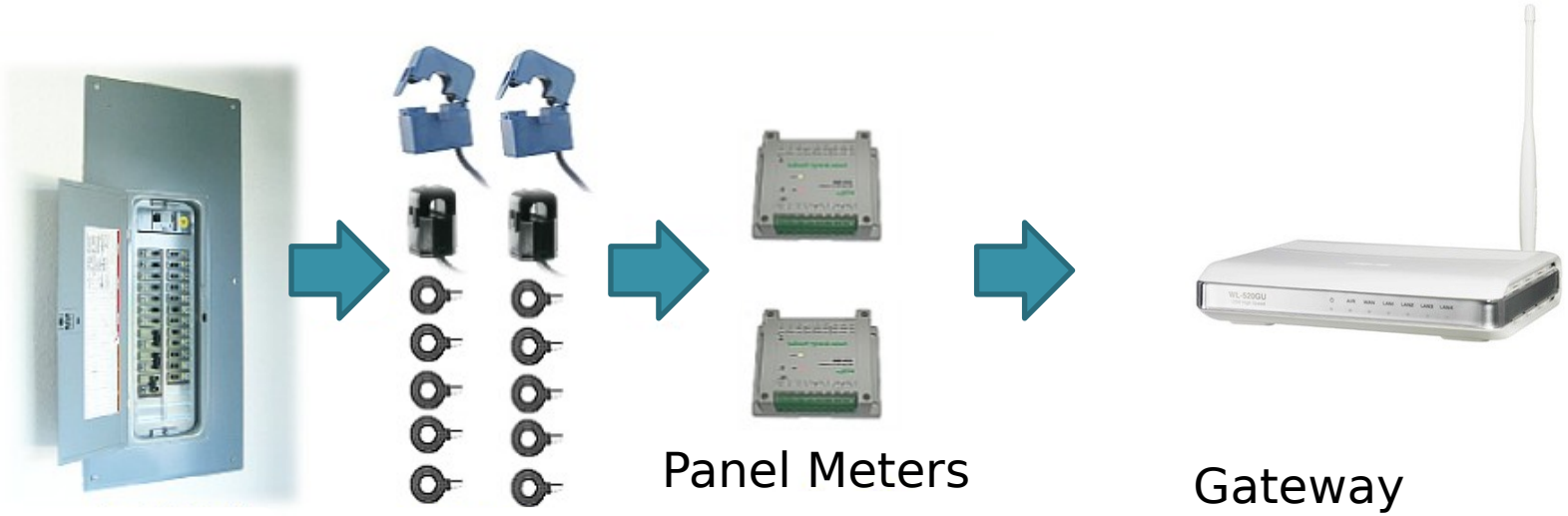


Apartment	Square Ft.	Rent
1 BR	595	$1,143
2 BR	790-845	$1,296-$1,361
3 BR	1035	$1,538

Experimental site location



Energy Metering Technology

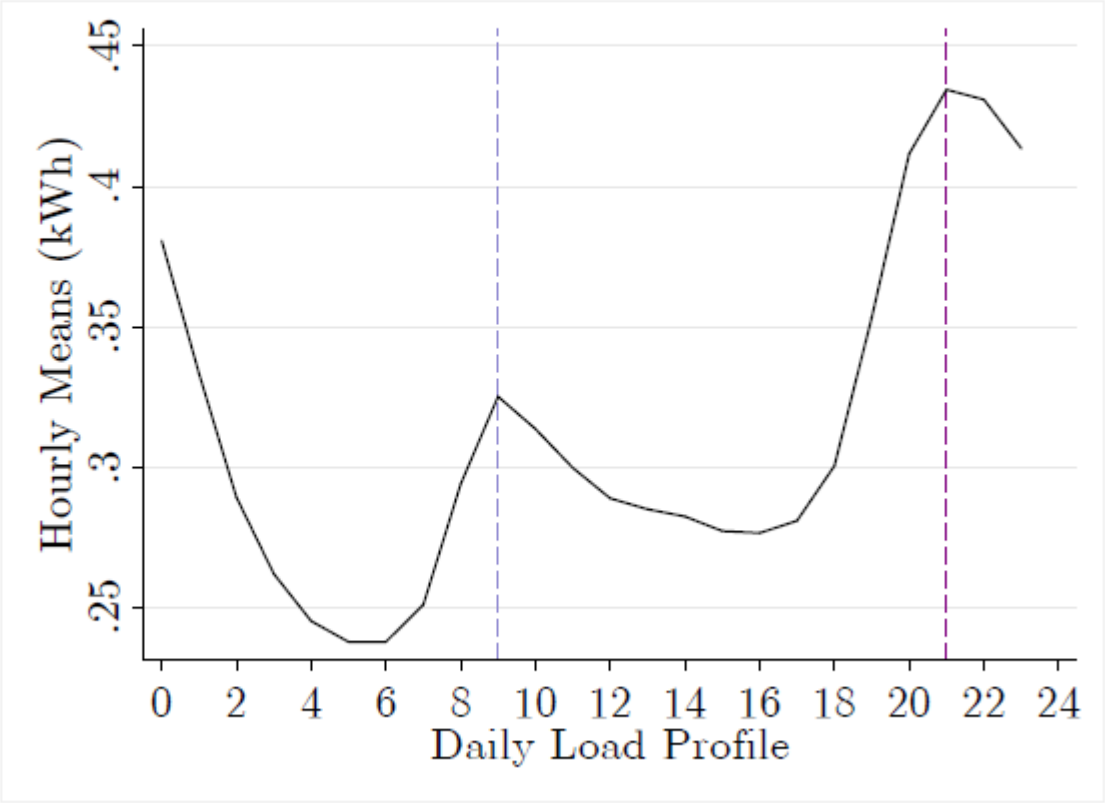


For more information on the engineering technology, see
Chen VL, Delmas MA, Kaiser WJ (2014) *Energy and Buildings* 70:455-462.

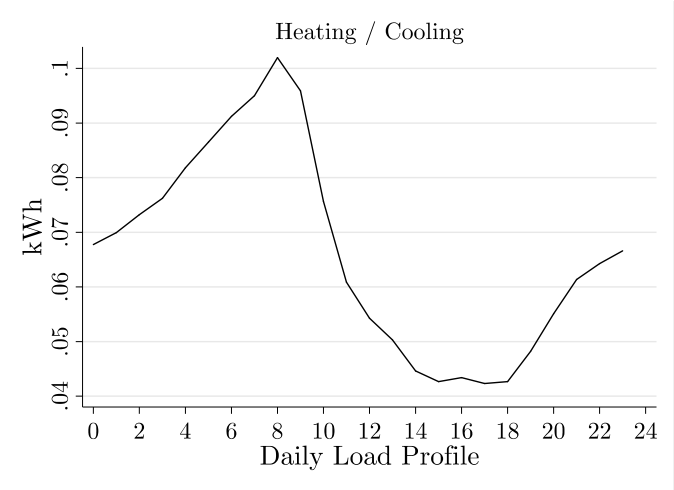
Community Load Profile

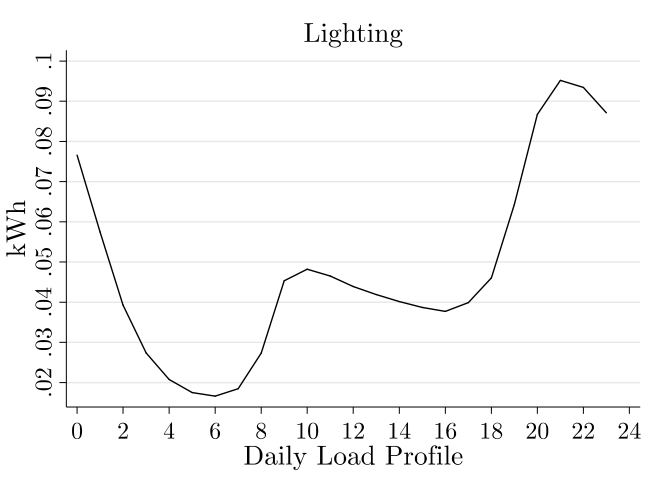
Daily Load Profile

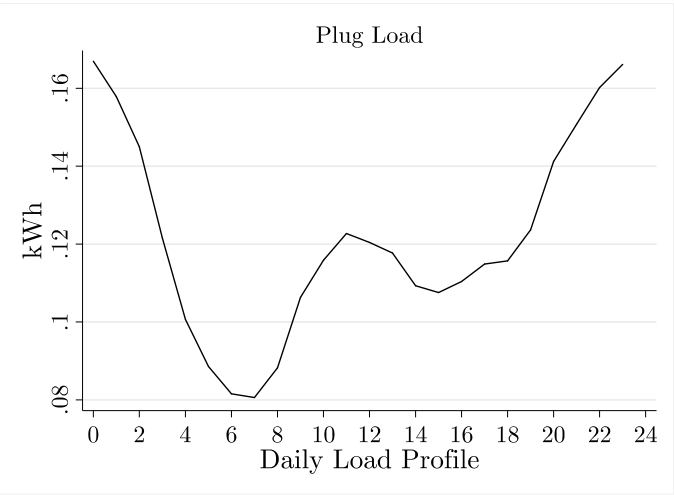
Peak consumption for community occurs at 9 am (mornings) and 9pm (evenings)

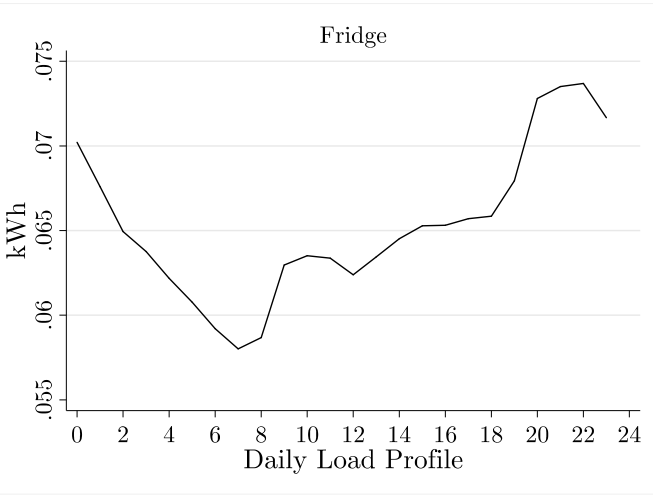


Load Profiles

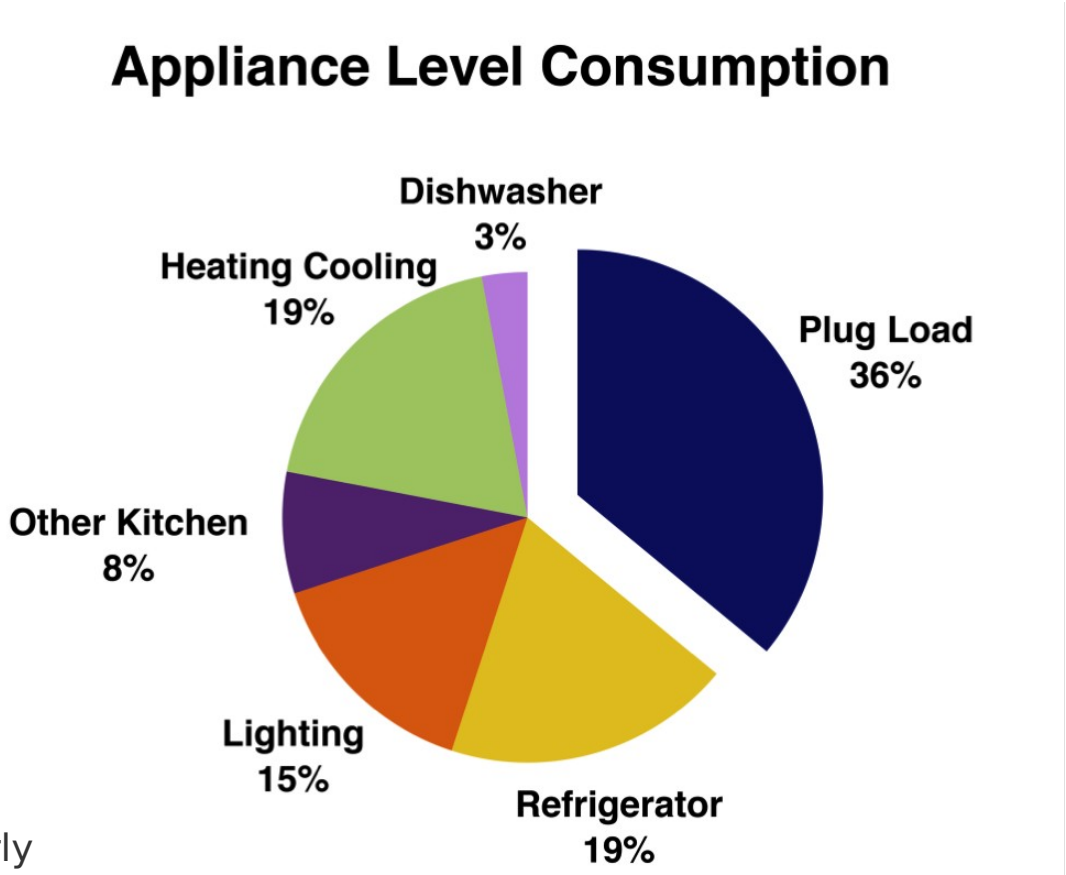








Appliance Level Results



N=490,994 hourly kWh observations
118 apartments

Includes all household electricity uses

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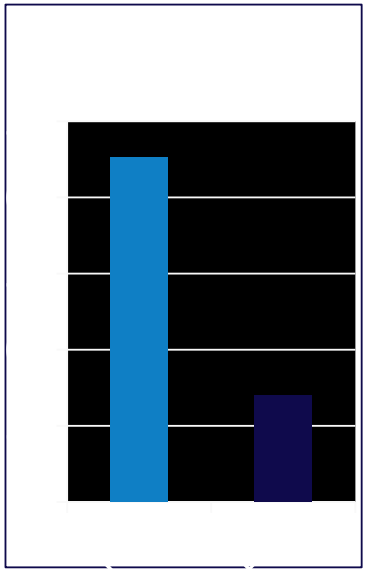
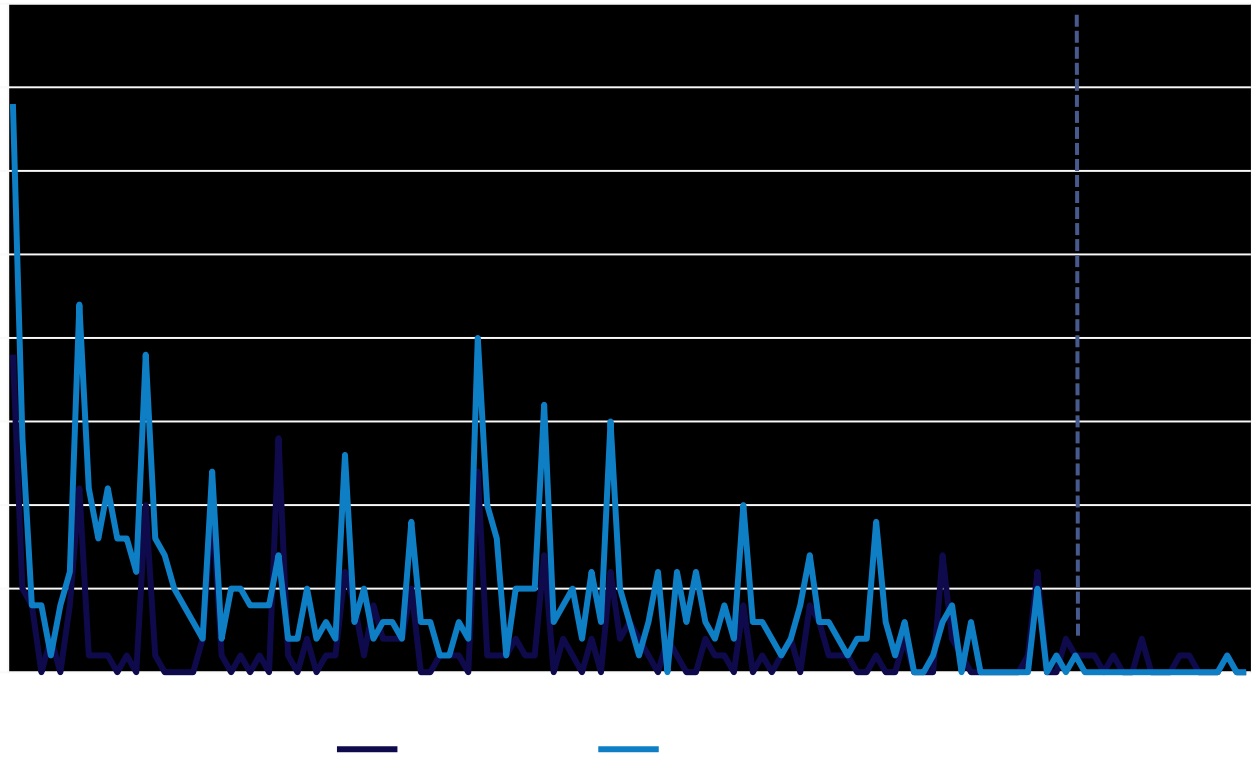
Results

Consumer Engagement
Google Analytics



End of experiment



Focus group

The **pie chart** had a big impact. It helped us see what the highest impact was. We started turning off the TV and the DVR. So anywhere we could change it we did that.

It really changed my **habits**. But it didn't motivate me to purchase something that was more efficient.

There was definitely a **novelty effect**. I found myself removing cereal boxes from the top of the refrigerator and we found that helped with consumption.

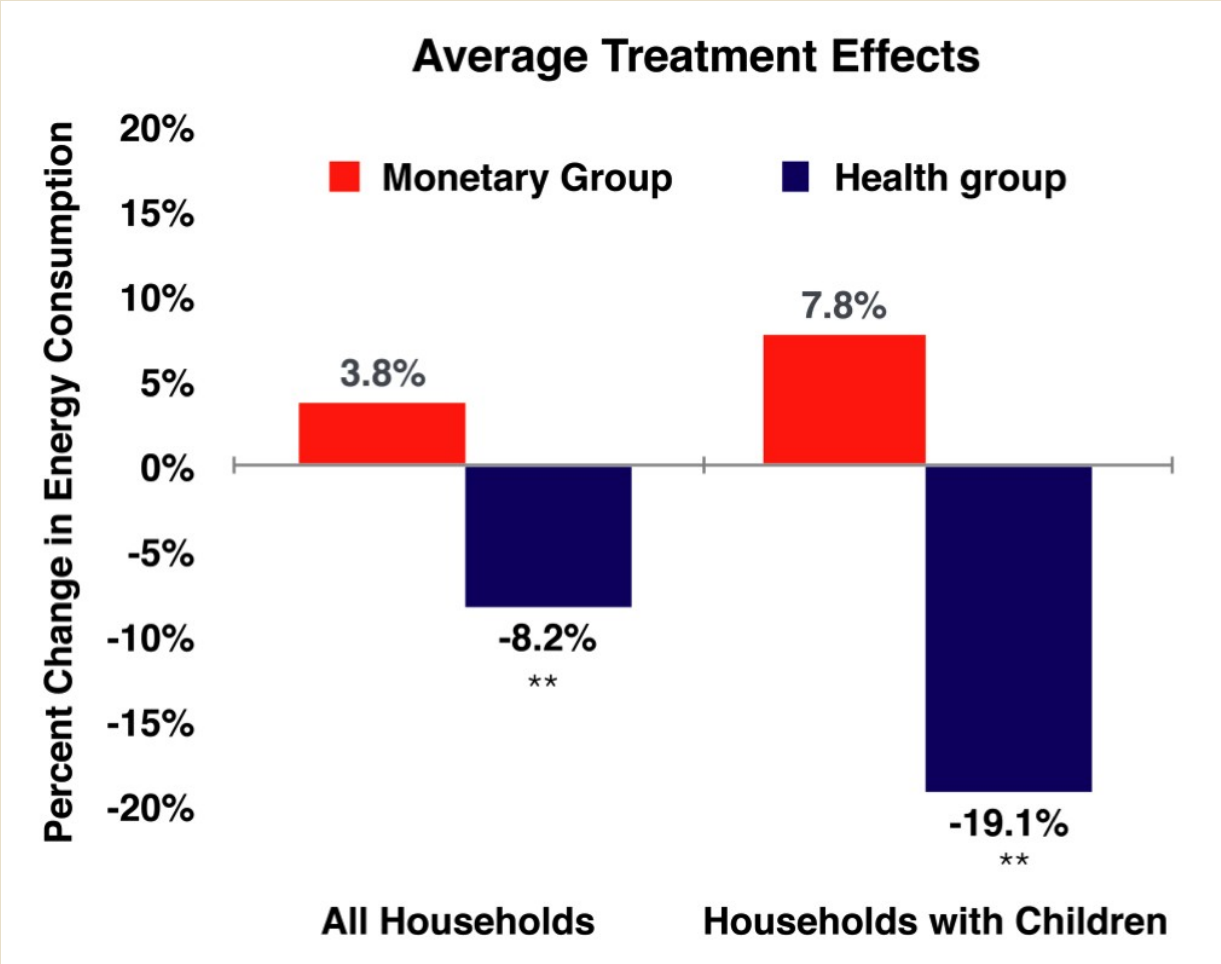
I liked the **real time** information, I realized how much energy the printer was consuming.

The **real time** data was kind of disheartening. I learned as a kid to turn the light off, but I learned that it did not make much of a

I felt a bit **shamed**. The other thing that was interesting was to see **other people change**. You saw somebody change from red to green. Seeing other people change their energy usage made me think that maybe there was something you could do.

I always thought of myself as efficient. In our old apartment we had such a low bill, I thought we must be efficient. But now I am more aware that there are **people who are more frugal**. I try to pull out the chargers, I try to not leave the laptop in.

Main Treatment Effects



N=490,994 hourly kWh observations
118 apartments

IIITD/UCLA ENGAGE

Why India?

- In India, 66% of the electricity generation is derived from coal power plants and is a major source of air pollution.
- Emissions from these plants, result in an estimated 80,000–115,000 premature deaths and more than 20 million asthma cases from exposure to total particulate matter (PM) 2.5 pollution annually (Guttikunda and Jawahar, 2014).

Survey of 1,820 respondents in Urban Delhi

	Motivation										
Action	Money	Habit	Necessity	Health	Future Generations	Environmental Friendly	Trends	Ethical/ Moral	Cultural	Other	No Response
Unplug Appliances	70.42	29.19	6.72	.58	3.27	8.9	.26	2.3	.26	4.99	.77
	(1100)	(456)	(105)	(9)	(51)	(139)	(4)	(36)	(4)	(78)	(12)
Buy Energy Efficient Appliances	61.58	10.57	9.81	.90	6.91	21.08	4.01	1.73	.14	4.91	.90
	(891)	(153)	(142)	(13)	(100)	(305)	(58)	(25)	(2)	(71)	(13)
Turn Off AC	65.94	22.75	12.06	.07	3.61	11.44	.41	2.32	.14	4.84	1.23
	(968)	(334)	(177)	(1)	(53)	(168)	(6)	(34)	(2)	(71)	(18)
Turn Off Lights	60.3	23.31	10.3	2.39	3.87	13.1	.82	2.39	.16	7.58	1.65
	(732)	(283)	(125)	(29)	(47)	(159)	(10)	(29)	(2)	(92)	(20)
Change Appliance Settings	38.71	18.55	10.38	11.49	2.62	14.21	2.32	3.23	.3	13.81	2.82
	(384)	(184)	(103)	(114)	(26)	(141)	(23)	(32)	(3)	(137)	(28)

Notes: This table summarizes the motivations for taking energy conservation behaviors for the respondents that said they take action always or often. Respondents were able to list more than one motivation. The number of respondents in each category is listed in parentheses.

UCLA IIID Engage

Start Page | Energy Saving Tips | About Engage | Engage Team | Contact Us

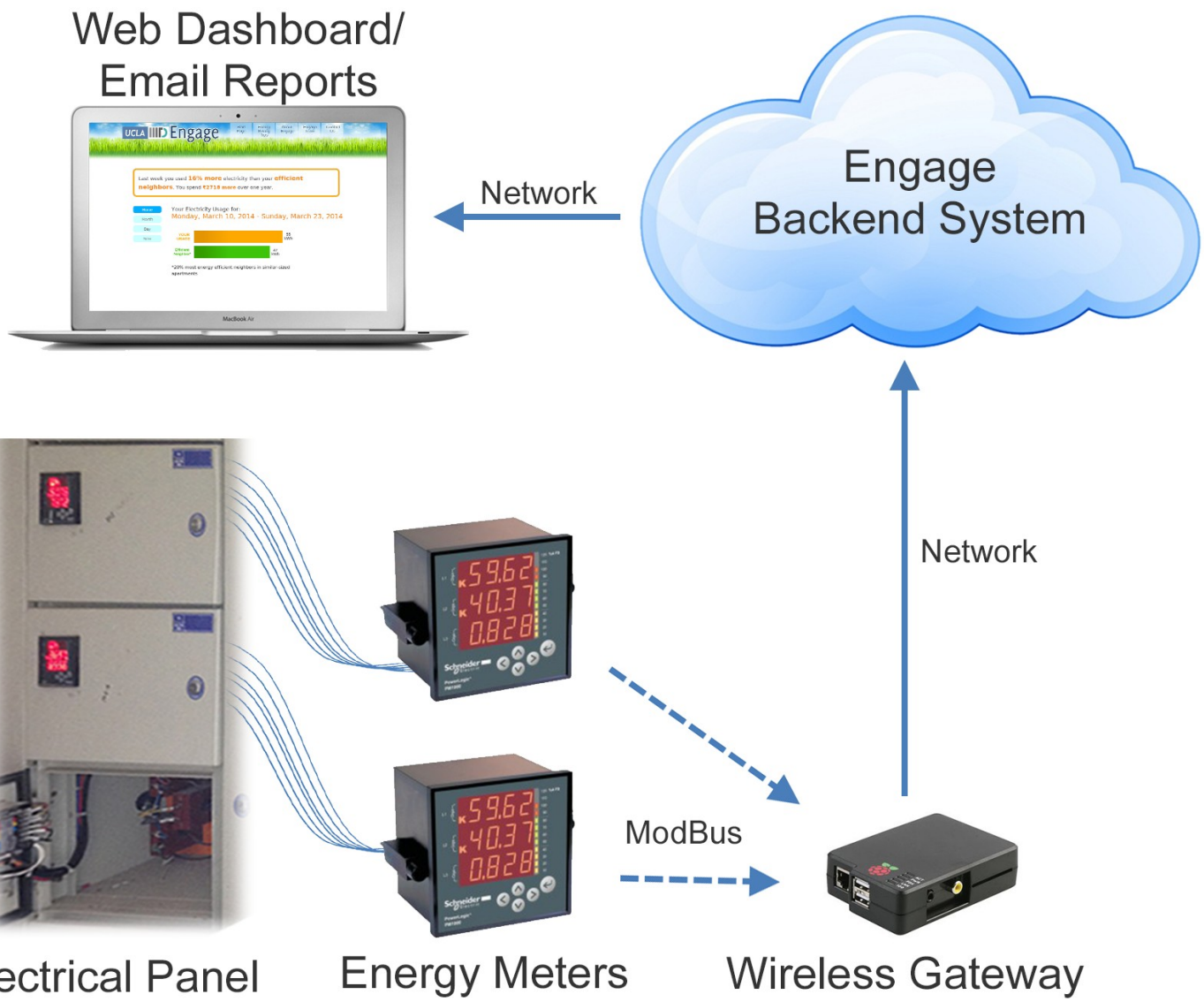
Last week you used **16% more** electricity than your **efficient neighbors**. You spend **₹2718 more** over one year.

Home
Month
Day
Now

Your Electricity Usage for:

Monday, March 10, 2014 - Sunday, March 23, 2014

*20% most energy efficient neighbors in similar-sized apartments

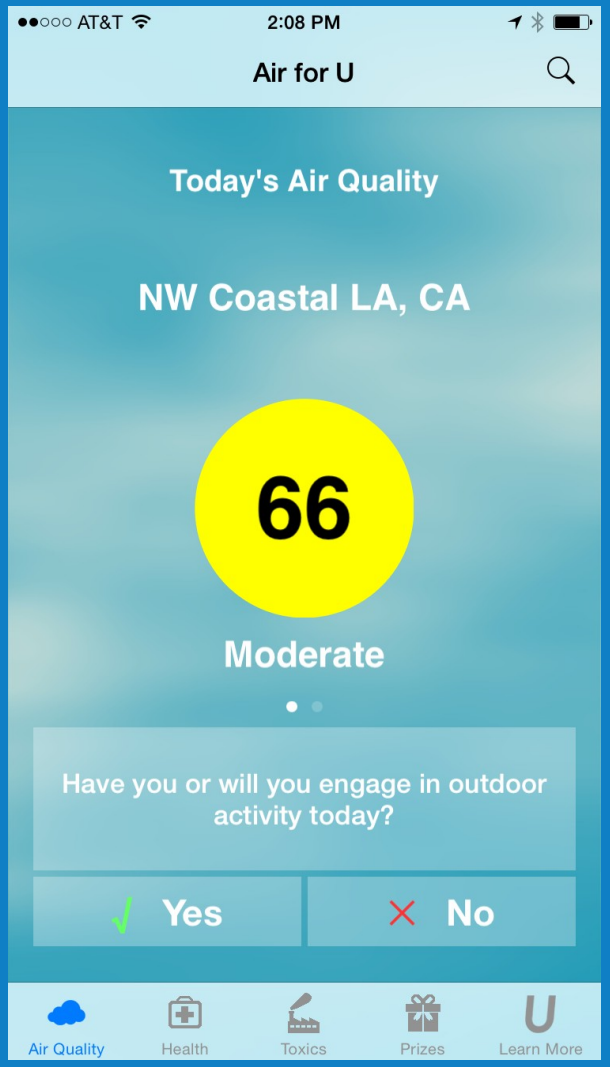

Web Dashboard/
Email Reports
Network
Engage
Backend System
Network
ModBus
Electrical Panel
Energy Meters
Wireless Gateway

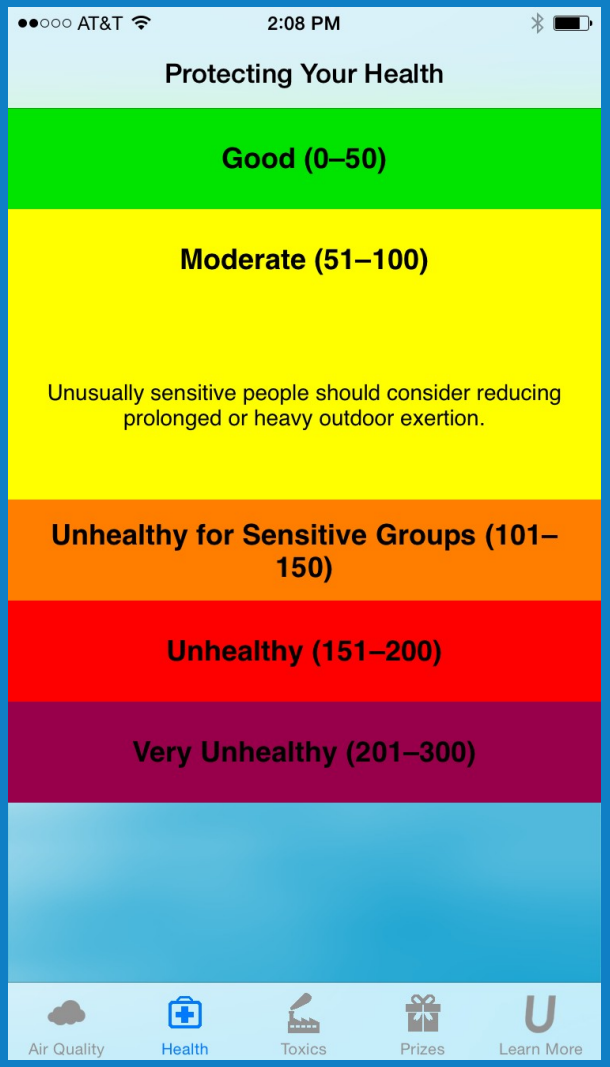
Results

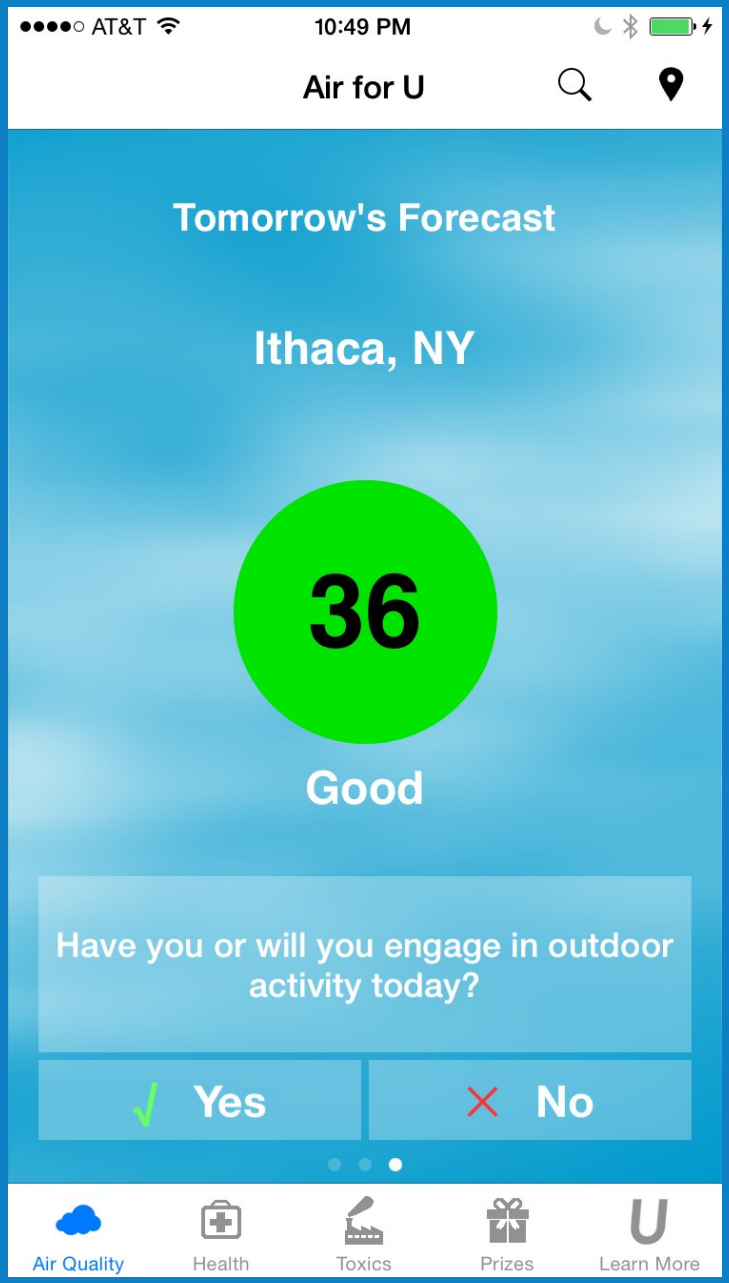
- Households in the environmental/health group accessed the online energy-monitoring dashboard more frequently and reduced their electricity usage by 18.4%.
- Based on the weekly treatment messages, the median household in the financial group saw a potential savings of 327 Rupees per month if they reduced their electricity consumption to the level of their efficient neighbor.
- This is enough to buy roughly two gallons of milk or just over one gallon of gasoline.
- Several said that the savings presented in the treatment messages were not sufficiently large to motivate them to conserve.

AirForU

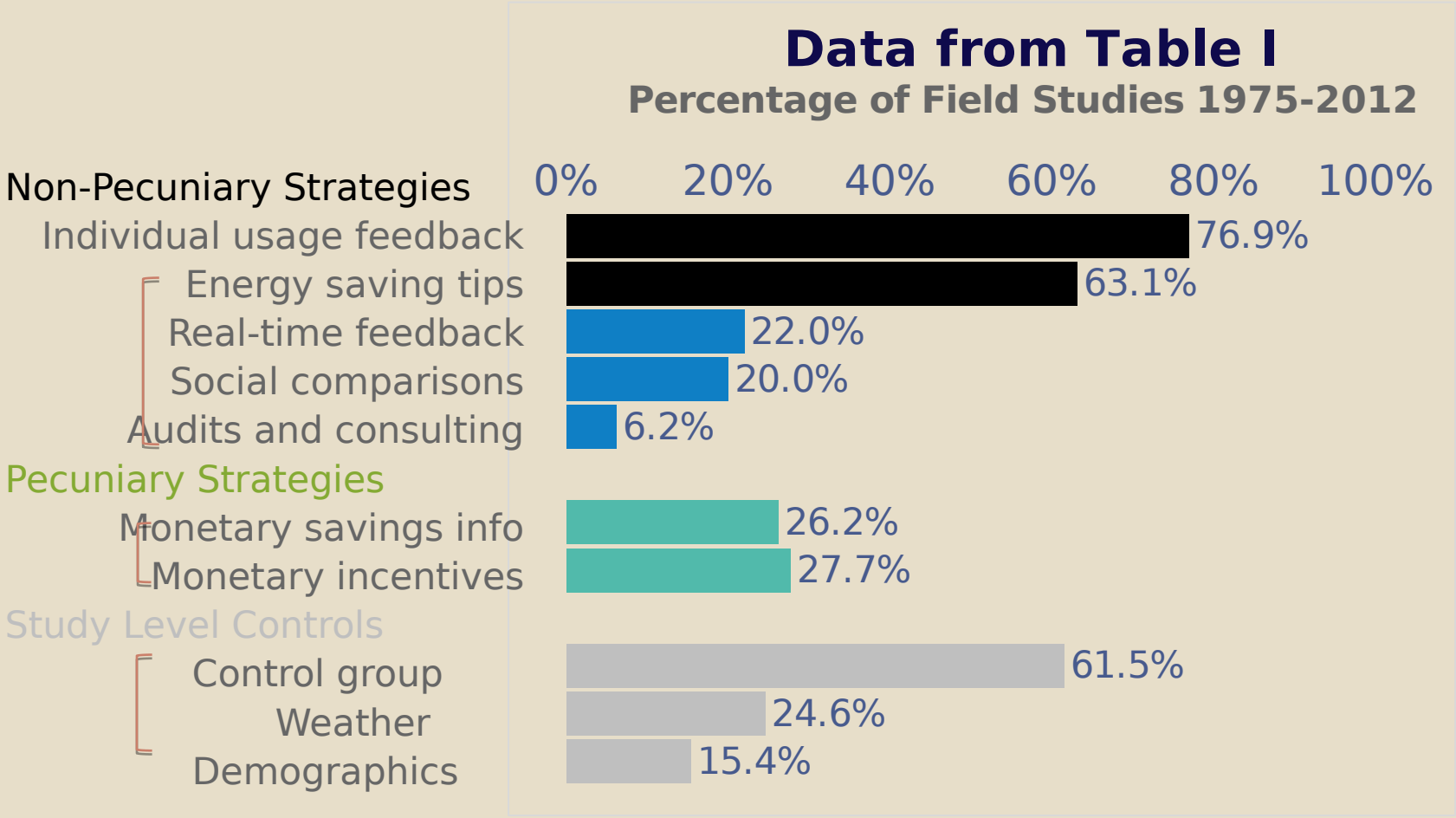
AirForU


●●○○○ AT&T
2:08 PM
Air for U
Today's Air Quality
NW Coastal LA, CA
66
Moderate
Have you or will you engage in outdoor activity today?
Yes
No
Air Quality
Health
Toxics
Prizes
Learn More


●●○○○ AT&T
2:08 PM
Protecting Your Health
Good (0–50)
Moderate (51–100)
Unusually sensitive people should consider reducing prolonged or heavy outdoor exertion.
Unhealthy for Sensitive Groups (101–150)
Unhealthy (151–200)
Very Unhealthy (201–300)
Air Quality
Health
Toxics
Prizes
Learn More


AT&T
10:49 PM
Air for U
Tomorrow's Forecast
Ithaca, NY
36
Good
Have you or will you engage in outdoor activity today?
Yes
No
Air Quality
Health
Toxics
Prizes
Learn More

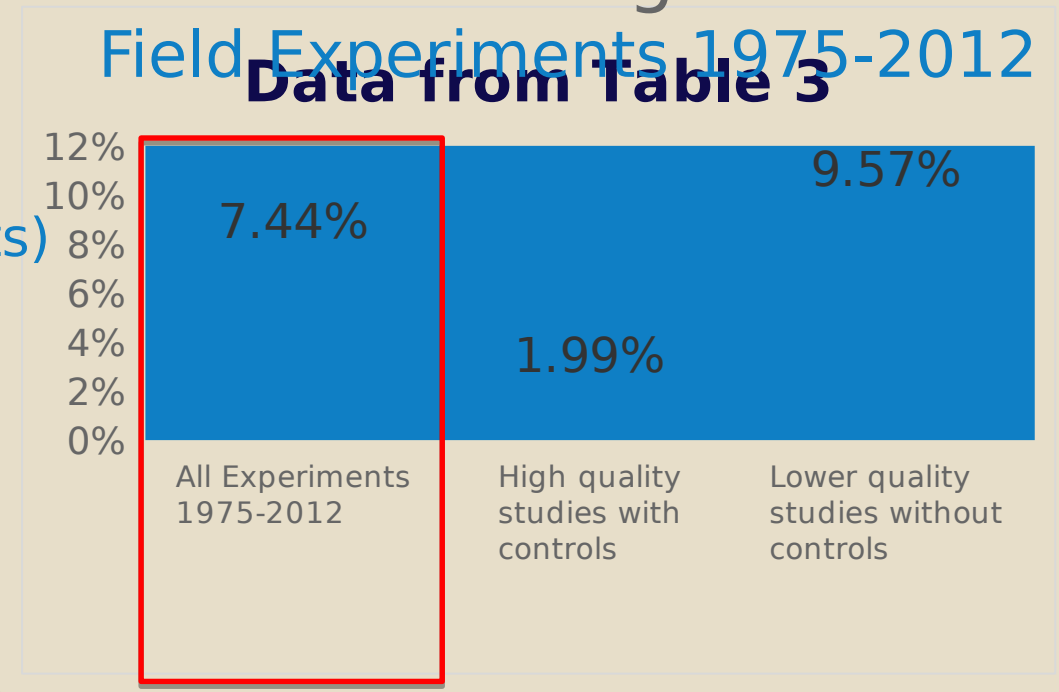
Meta-Analysis
Information Strategies



* Published studies sometimes include multiple treatments so they do not add up to 100%

Meta-Analysis Summary of Treatment Effects

N=156 field trials
(524,479 study subjects)



Energy Policy 61, 729-739
October 2013

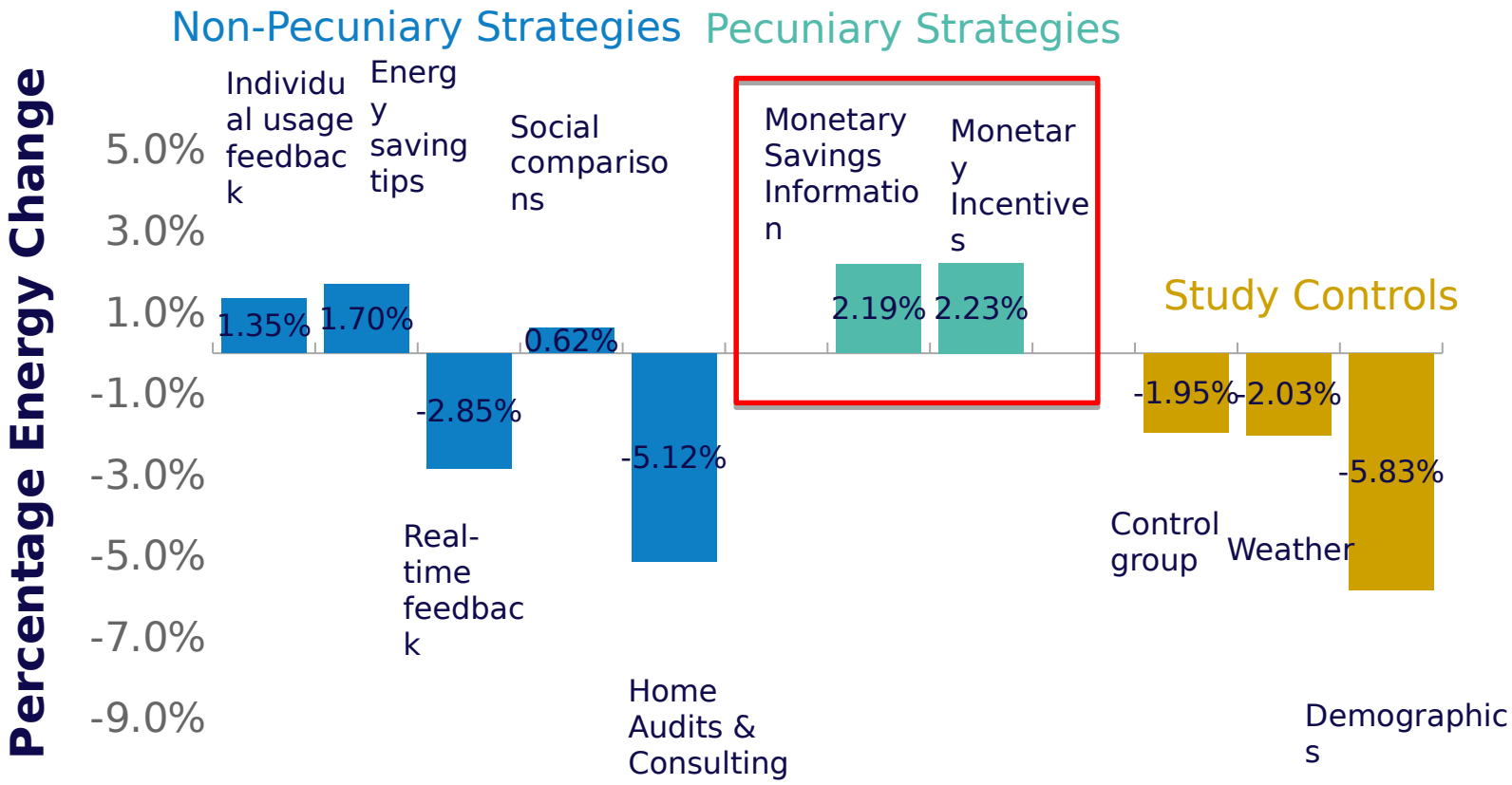
* Controls include weather, demographics or control group

Meta-Regression Estimates

N=156 field trials
(524,479 study subjects)

Pooled Meta-Regression

Field Experiments 1975-2012



Energy Policy 61, 729-739
October 2013

* Negative values mean energy savings

Table 4. Treatment Effects by Appliance

Study Variables	(4) Heating Cooling	(5) Lighting	(6) Plug Load	(7) Refrigerator	(8) Dishwasher	(9) Other Kitchen
Experimental						
Post-Treat*Monetary Savings Group	9.561***	-11.17***	3.754***	22.43***	21.59***	-2.239***
	(1.135)	(0.406)	(0.338)	(0.295)	(0.782)	(0.650)
Post-Treat*Health Group	10.06***	-13.14***	-5.254***	17.72***	9.937***	-1.256**
	(1.043)	(0.407)	(0.334)	(0.289)	(0.802)	(0.632)
Household Characteristics						
Adults	-38.16***	-9.076***	3.067***	12.42***	17.77***	29.31***
	(1.547)	(0.423)	(0.269)	(0.264)	(0.687)	(0.492)
Children	6.775***	7.538***	10.19***	6.656***	-3.256***	10.53***
	(0.463)	(0.141)	(0.116)	(0.0989)	(0.294)	(0.268)
Apartment Size (No. of bedrooms)	44.20***	25.22***	-36.73***	32.67***	23.55***	40.84***
	(1.755)	(0.562)	(0.419)	(0.381)	(1.109)	(1.045)
Floor Plan (Nominal square footage)	-0.111***	-0.0314***	0.147***	-0.0945***	-0.0469***	-0.130***
	(0.00601)	(0.00188)	(0.00147)	(0.00128)	(0.00361)	(0.00339)
Building Floor	4.508***	-0.903***	5.283***	12.11***	-0.229	-3.749***
	(0.393)	(0.129)	(0.104)	(0.0928)	(0.261)	(0.234)
Ideology						
Member Environmental Organization	-16.31***	-3.574***	-1.808***	-7.868***	-20.28***	13.01***
	(0.901)	(0.323)	(0.279)	(0.254)	(0.563)	(0.689)
Weather Controls						
Heating Degree Hours	2.127***	0.0221	0.217***	-0.289***	0.211***	-0.0274
	(0.0810)	(0.0295)	(0.0239)	(0.0212)	(0.0524)	(0.0499)
Cooling Degree Hours	0.262	-0.268***	-0.116**	0.170***	-0.0456	-0.00310
	(0.166)	(0.0600)	(0.0489)	(0.0433)	(0.107)	(0.102)
Time Dummies						
Hour-by-Day	Yes	Yes	Yes	Yes	Yes	Yes
Day-by-Week	Yes	Yes	Yes	Yes	Yes	Yes
Weekly Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	120.7***	80.34***	3.268***	76.38***	3.889*	19.06***
	(4.070)	(1.286)	(1.013)	(0.902)	(2.311)	(2.079)
Observations	490,994	490,994	490,994	490,994	490,994	490,994
Number of Apartments	118	118	118	118	118	118
Wald chi-square (*d.f.* = 53)	4,382***	98,075***	50,526***	57,229***	8,770***	12,056***

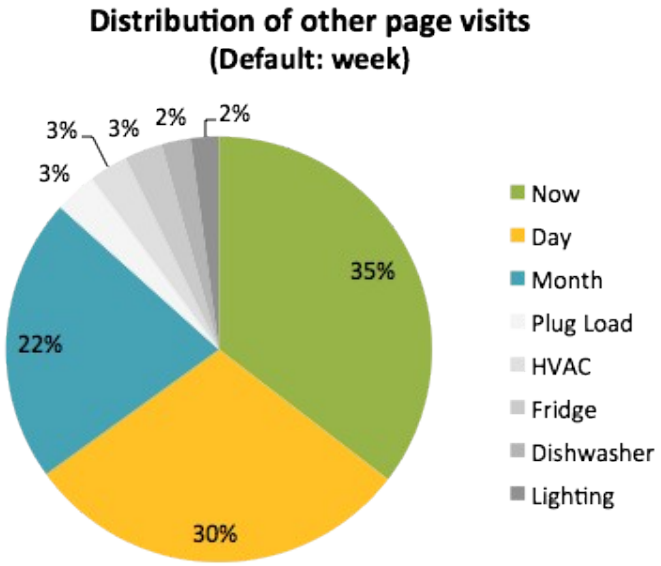
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

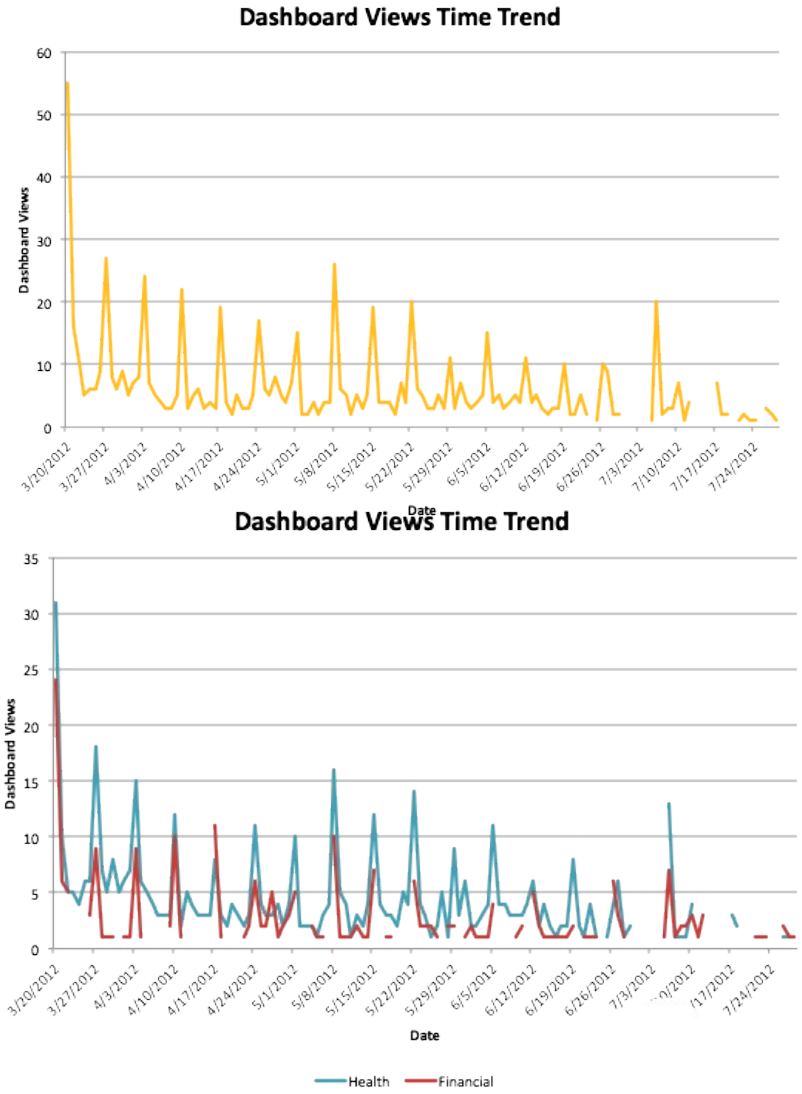
Table 5. Treatment Effects by Time of Day

Study Variables	(10) Midnight - 3:00am	(11) 3:00-6:00am	(12) 6:00-9:00am	(13) 9:00-12:00pm	(14) 12:00-3:00pm	(15) 3:00-6:00pm	(16) 6:00-9:00pm	(17) 9:00-Midnight
Experimental								
Post-Treat*Monetary Savings Group	**8.736*** **	**5.938*** **	**2.099*** **	**-2.226** **	**-0.624**	**0.376**	**-2.577** **	**2.160***
	(0.925)	(0.650)	(0.734)	(0.981)	(0.933)	(0.878)	(1.139)	(1.152)
Post-Treat*Health Group	**-2.418*** **	**1.933*** **	**-0.915**	**-7.769*** **	**-7.364*** **	**-4.825*** **	**-11.33*** **	**-10.18*** **
	(0.891)	(0.634)	(0.716)	(0.937)	(0.899)	(0.850)	(1.091)	(1.100)
Household Characteristics								
Adults	-2.278**	-10.64***	-16.39***	-12.02***	2.174**	3.566***	5.496***	7.024***
	(0.942)	(0.823)	(0.924)	(1.035)	(0.900)	(0.837)	(1.026)	(1.073)
Children	9.186***	7.614***	10.63***	14.69***	13.61***	15.08***	15.41***	11.34***
	(0.347)	(0.245)	(0.290)	(0.369)	(0.346)	(0.340)	(0.413)	(0.420)
Apartment Size (No. of bedrooms)	19.41***	13.40***	27.10***	28.46***	28.02***	20.18***	34.09***	49.39***
	(1.409)	(0.967)	(1.126)	(1.477)	(1.346)	(1.276)	(1.669)	(1.766)
Floor Plan (Nominal square footage)	-0.0141***	0.00725**	-0.0195***	-0.0154***	-0.0229***	0.0153***	0.00991*	-0.0341***
	(0.00478)	(0.00321)	(0.00371)	(0.00494)	(0.00458)	(0.00432)	(0.00560)	(0.00600)
Building Floor	6.503***	3.413***	7.295***	5.933***	6.182***	6.727***	8.580***	11.60***
	(0.313)	(0.222)	(0.242)	(0.320)	(0.296)	(0.276)	(0.371)	(0.384)
Ideology								
Member Environmental Organization	-4.665***	-1.916***	-7.103***	-4.557***	-0.479	1.570*	-8.770***	-13.30***
	(0.850)	(0.633)	(0.627)	(0.822)	(0.751)	(0.810)	(1.021)	(1.045)
Weather Controls								
Heating Degree Hours	0.842***	0.505***	0.386***	0.927***	0.408***	0.653***	0.892***	1.091***
	(0.0705)	(0.0475)	(0.0498)	(0.0873)	(0.0958)	(0.0831)	(0.104)	(0.102)
Cooling Degree Hours	1.719	-6.860**	0.150	-0.0393	-0.272***	0.133	0.285	0.171
	(2.715)	(3.218)	(0.467)	(0.112)	(0.0856)	(0.115)	(0.384)	(0.825)
Time Dummies								
Hour-by-Day	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-by-Week	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weekly Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	69.12***	36.58***	52.51***	43.62***	19.92***	-5.017**	2.155	10.22***
	(2.855)	(2.221)	(2.376)	(2.876)	(2.606)	(2.470)	(3.246)	(3.423)
Observations	60,942	60,433	61,206	61,543	61,402	61,581	61,891	61,996
Number of Apartments	118	118	118	118	118	118	118	118
Wald chi-square (*d.f.* = 32)	6,118***	4,367***	7,877***	5,593***	5,712***	6,218***	7,442***	6,530***

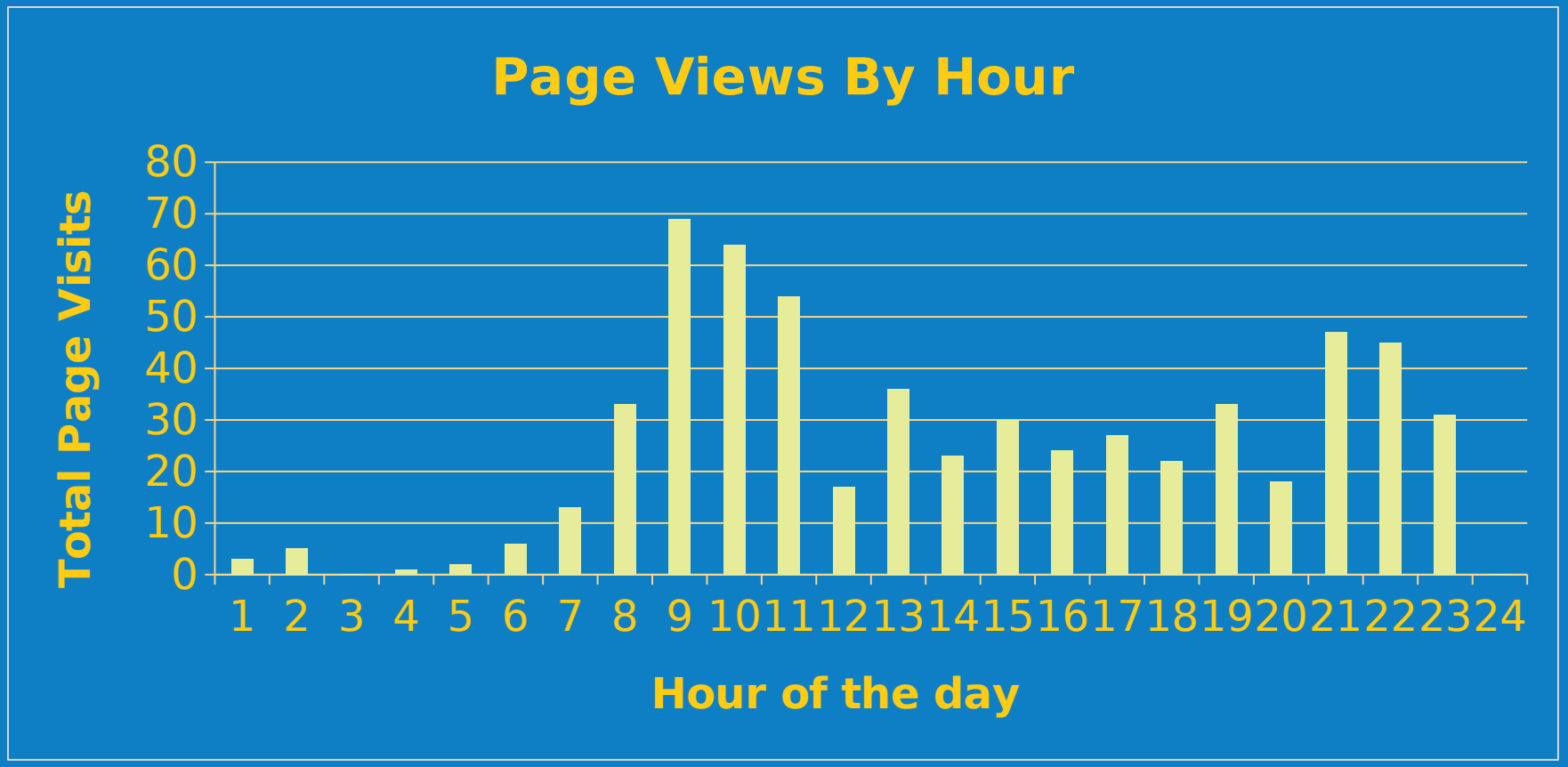
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Website usage





What Time Do They View Dashboards?



Highest Website Traffic: **9-11 am and 9-11 pm.**